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MYCOLOGICAL SERIES—BULLETIN No. 5.

DEPARTMENT OF AGRICULTURE

MYSORE STATE

BLACK ROT OR KOLEROGA OF COFFEE IN MYSORE

BY

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FOREWORD.

THE study of Black Rot of Coffee was taken up by the Mycological Section of the Department as early as 1913, and was continued with a number of breaks till 1919. Publication has been delayed because I had hoped that we should be able to round off the investigation. This has not been possible owing partly to pressure of other work and partly to lack of facilities as we have not had a suitable area under our control for continuous study and field experiment. The information which we have already collected is however of sufficient interest and practical importance to warrant its publication.

The field work has been carried out by the two junior authors under my general direction. The laboratory work has been done by all three of us.

LESLIE C. COLEMAN,
Director of Agriculture.

MARCH 1923.

BLACK ROT OR KOLEROGA OF COFFEE IN MYSORE.

THE disease of Coffee known throughout the South of India as Black rot and in Mysore as Koleroga was first fully described by Dr. M. C. Cooke[1] in 1876 in a report to the Government of India entitled "Report on Diseased Leaves of Coffee and other Plants." In this report, he first gives the name, Pellicularia koleroga to the fungus causing the disease.

Cooke [2, 3] gave a scientific description of this fungus at about the same time, while further a publication[4] by him on the same subject appeared in the Popular Science Review Vol. LIX. This last publication we have not been able to see.

The same or a similar disease was reported by Ernst[5] from Venezuela at nearly the same time, while Cockerell[6] described it from Jamaica in 1893. In both of these latter localities it had been known before 1870. Since then what appears to be the same disease has been found in Java, New Caledonia,[7] the Belgian Congo,[8] Porto Rico and Guatemala,[9] so its distribution may be considered as almost throughout the tropics.

The characteristic features of the disease are the discoloration of the leaves and berries attacked and the presence of a fungus web or pellicle which grows over the lower surface of the leaves and over the berries. The web constricts itself at the petiole of the leaf to a rather tough strand which extends on to the leaf-bearing twig

[1] M. C. Cooke—"Report on diseased leaves of Coffee and other Plants." Report to Government of India, 1876.

[2] M. C. Cooke—Some Indian Fungi: Grevillea Vol. IV, 1875-76, p. 116.

[3] M. C. Cooke—Affinities of Pellicularia: Grevillea Vol. IV, 1875-76, p. 134.

[4] M. C. Cooke—Popular Science Review, 1876, Vol. LIX, p. 161 cited after Delacroix, Les Maladies des Caféiers, 2me Édition, 1900.

[5] Ernst—Botanische Notizen aus Caracas: Botanische Centralblatt, 1880, p. 1178—1179.

[6] Cockerell—Gardeners' Chronicle, XVIII, 1893, p. 303.

[7] Gallaud—Comptes Rendus: 1905, T. CXLI, p. 898.

[8] E. de Wildeman—Comptes Rendus, T. CXLII 1906, p. 1003.

[9] Brick—Jahresber. d. Verein f. angew. Botanik, 1908, p. 239

and from here may extend on to other leaves and twigs. Frequently when the leaf dies and the petiole breaks loose from the twig the whole leaf hangs suspended by the fungus strand. In fact this is a very characteristic feature of the disease (See Plate 1, Fig. I). The strands can usually be traced from the leaves to the small branches and the branches of the next order. Very rarely are they to be found on the main stem and in no case have we been able to trace them to the ground.

The fungus web consists of a mass of interwoven mycelial threads with here and there a primary strand consisting of a number of hyphæ running parallel to each other. The strands on the leaf petioles and the twigs consist of a rather closely compacted ribbon of parallel hyphæ. The strands on the surface of the leaves and on the twigs consist of hyphæ of a light brownish colour, the younger hyphæ which branch off from them being quite hyaline.

As far as we have been able to ascertain, the fungus grows quite superficially, there being no evidence of haustoria penetrating the epidermal cells of the leaf.

As already stated both leaves and berries are attacked. Long before these show any visible injury the fungus is present as a fine whitish mildew-like growth covering a part of the surface. This is easily seen only when the surface of the leaf is comparatively dry (Pl. I, Fig. 2). During rains when the leaves are dripping with water this early fungus growth can be made out only with difficulty. With the spread of the fungus the leaf or berry takes on a brownish and finally an almost black colour which has given rise to the popular name 'Black Rot' commonly applied to the disease.

The disease is definitely connected with the rainy season and occurs seriously only in areas where and during seasons when the rainfall during the monsoon is almost constant and where the air continues heavily laden with moisture. It is therefore most severe in coffee areas with a high rainfall. Estates with a rainfall of between 60 and 70 inches are rarely, if ever seriously, attacked. But the continued presence of a moisture-laden air is more important for the spread of the disease than is a high precipitation. Thus during the past monsoon (1922) when we had a long continued but not excessive rainfall the disease has been particularly bad.

The disease occurs most severely in portions of an estate sheltered from the wind where the mist hangs heavily. An atmosphere saturated with moisture furnishes the most favourable conditions for the growth of the fungus. Other conditions favouring its spread will be discussed later.

As already stated Cooke[1] described this fungus as Pellicularia koleroga and placed it in the group Mucedinæ. He did this on the basis of certain spherical bodies which he found associated with the fungus which he took to be conidiospores (see Text Figure I). In 1913 the senior author while examining the fungus in a field laboratory discovered that the fungus does not belong to this group at all but to the great group of Basidiomycetes. Some of the spherical structures seen and figured by Cooke as young spores were simply the spherical basidia upon which the basidiospores are borne. The other echinulate bodies which Cooke looked upon as mature spores have been shown pretty conclusively by Fawcett[2] to belong to another species altogether which has become associated with the real black rot fungus. As a matter of fact in all our microscopic examinations of diseased material we have never seen any of these echinulate spores.

TEXT FIGURE I.

The senior author read a paper before the Indian Science Congress in January 1914 giving the main facts stated above and proposing the name Hypochnus koleroga for the fungus as the species seemed to fall most fittingly under the genus Hypochnus than under any other. It was only later that he discovered that Von Höhnel[3] had already, in 1910, on the basis of material

[1] M. C. Cooke—Loc. Cit.

[2] Fawcett—Journal of Agricultural Research, Washington, 1914, p. 231.

[3] Von Höhnel: Fragmente zur Mykologie X; Sitzb. k. Akad. Wiss. Wien, Math-Natur Wiss. klass. CXIX, I. p. 395, 1910.

studied in the Kew Herbarium ascertained that the fungus is a Basidiomycete and described it quite fully and on the whole accurately as Corticium koleroga. The two genera Corticium and Hypochnus are so closely related that they should be considered as one and the same genus.

As Von Höhnel's description is given in a publication which is not generally available we deem it advisable to give a translation here for general information.

"The fungus was described as a Hyphomycete in the Popular Science Review, 1876. It is, on the basis of the original specimen in the Kew Herbarium, a Corticium which must be called Corticium koleroga (Cooke) Von Höhnel.

"Fungus entirely superficial, widely spread, forming a thin, soft and pale pellicle; primary hyphæ running straight, thin-walled, mostly pale brown, 6—7 μ wide, hyphal cells up to 120 μ long without clamp connection, with both opposite and alternate branching; branches thin-walled, hyaline, provided with branches which stand almost vertical. These cross each other many times forming a loose pellicle. Basidia oval-spherical, 8—11 μ in diameter with two to four obtuse sterigmata which are approximately 2 μ long; the basidia arise in a bunch of 2 to 5 from the ends of short lateral branches which are from 4—12 μ long. Spores hyaline, very thin-walled, straight or somewhat curved, elongate, club-shaped, flattened on one side, rounded at the end, wider below and with a lateral point of attachment 10—12 $\mu \times 4$—4·2 μ.

"This species is certainly different from Hypochnus gardeniæ, Zimm, Hyp. theæ Bern. (Bull. Dept. Agri., Indes Nederland, No. 6 Buitenzorg, 1907, P. 16) and Corticium javanicum, Zimm. (Centr. f. Bakt., Abt. II, Bd. 7, 1901).

"Cooke did not see the spores of the fungus and took the basidia to be spores."

The above description considering that it was made from herbarium material is singularly accurate. Nevertheless it is imperfect and incorrect in certain important points.

The accompanying figures which are taken from microphotographs show the actual appearance of the fungus. Pl. II, Fig. 1 taken under a low power shows

the mycelial web from the under surface of a leaf with the basidia already formed. These are the organs which Cooke took to be immature spores. There is no sign of these arising in bunches of 2—5 from the ends of lateral branches as described by Von Höhnel. There is no indication of this in the photograph nor have we been able to find this state of affairs in any of the material examined by us. A more serious mistake is that in regard to the sterigmata. These are not as stated by Von Höhnel, blunt and short. They are long and drawn out to a point. Instead of being only 2 μ long they are actually from 9 μ—11·5 μ in length as measured on freshmaterial. These structures are shown clearly in Plate II, Fig. (2) and Pl. III, Fig. 2. The measurements of the spores as given by Von Höhnel are considerably greater than we have found. Spores of fresh material measured 8 μ—9 μ long by 3·5 μ - 4.5 μ broad at the widest part. The basidia and spores as found on coffee are clearly shown in Pl. III, Fig. 2.

There is one other structure connected with this fungus which Von Höhnel did not see at all. These are dense clumps of hyphæ which develop at irregular intervals in the mycelial web towards the close of the monsoon. They are in the nature of sclerotia and developed for the definite purpose of carrying the fungus through the dry season. This has been established by one of us (M. J. Narasimhan) who found fresh hyphæ developing from these sclerotia-like bodies which had lain dormant through the dry season. He also observed direct infection taking place from old leaves which the fungus had attacked the previous year. Pl. III, Fig. 1 shows the apperance of these flat sclerotia under the microscope.

It may be wondered that notwithstanding the fact that this disease has been known since 1876 and has been examined by many scientists that up to the time of Von Höhnel's paper no one had observed the real spores of the fungus. The reason lies in the fact that the formation of basidiospores takes palce through only a short period. One of us (M. J. Narasimhan) has made the following observations in connection with a field study of the disease: The formation of basidia was first observed on a particular estate on 18th June 1919, the formation of sterigmata and basidiospores on 27th June. From this date till 6th July most of the affected leaves from

all over the estate showed the presence of basidiospores. After 6th July basidiospores could not be found at all though many leaves were examined. It may be pointed out in this connection that the spores become detached and washed away very easily so that soon after their full developmentthey disappear from the fungus web.

From the above observations and from the fact that many other observations made by all three of us show that basidiospores are not to be found late in the season it seems clear that the formation of basidiospores is of a very short duration and that if material is not collected during this very short period the fungus cannot be identified as a Basidiomycete.

The discovery of basidiospores enabled us to make pure cultures of the fungus. Small bits of the leaf on which the basidiospores were developing were stuck on the inner surface of the petri dish cover and were suspended over an oat agar medium in a petri dish. The basidiospores dropped on to the agar and germinated readily forming a fairly abundant growth. (See Pl. IV, Fig. 1) No extensive series of experiments could be tried on the ability of the fungus to grow on different culture media but it was grown on both sterilized potato cylinders (Pl. IV, Fig. 2) and oat agar so that it appears probable that it would grow on many different media. In no case was the growth accompanied by spore-formation.

Attempts were made to infect coffee plants with pure cultures of the fungus and with some measure of success. These experiments however had to be carried out at Bangalore where it was impossible to reproduce the monsoon conditions of the coffee area. Inoculations were made by placing small bits of the mycelium from pure cultures on the under surface of healthy coffee leaves. The plants were placed in a room in which a constant spray of water was kept playing. A considerable amount of growth on the under surface of the leaves took place but it was impossible to produce the typical symptoms found on the coffee estates. The growth ceased in every case before the under surface of the leaf was completely covered. Thus while the portion of the leaf, covered by fungus growth turned brownish black we were not able to produce a typical black rot under such artificial conditions.

What causes the death of the leaves and berries? In most cases of parasitic fungi, the fungus actually attacks

the cells of the host plant. Either it sends fungus hyphæ through the living cells thus bringing about their death or it penetrates such cells by means of haustoria, short branches formed for the special purpose. In the case of Corticium koleroga we have not been able to find evidence of any penetration of the host tissue. The parasite apparently simply lies on the surface of the organ attacked. It obviously must get the nourishment required for its development from the leaf or berry attacked. We have not been able to ascertain just how this is done as opportunity for continuous observation and experimentation in a field laboratory has been lacking. However, one of us (M. K. Venkata Rao) has been able to show that the presence of the fungus web on the leaf interferes seriously with the respiratory activity of the leaves attacked. He was able to obtain a reduction of from 25 per cent to 30 per cent in respiratory activity in freshly attacked leaves as compared with leaves free from attack. It seems highly probable that the fungus, in addition, secretes an enzyme or toxin which attacks the living protoplasm of the host tissue and that the death of leaves and berries is due to this as well as to the stoppage of the stomata. However, this is a matter which requires further careful investigation and we hope to take it up in the near future.

Other host plants.—The presence of C. koleroga on host plants other than coffee has already been reported. The statement frequently made that Cooke had reported it as attacking the Areca palm in Mysore is hardly correct. He simply reports the statement made by a coffee planter that the two diseases are identical. As a matter of fact all that the two diseases have in common is the vernacular name 'Koleroga' which means simply 'rot disease.' The disease of the Areca palm[1] is caused by Phytophthora arecæ a fungus belonging to an entirely different order. According to Raedt van Oldenbarnevelt[2], however, C. koleroga attacks Erythrina sp (Dadap) in Java but as far as I am aware [1] no further report of its attacking this tree has been published. Dr. Butler mentions in his "Fungi and disease in Plants," that the fungus has been observed on Strobilanthes, Dahlias, and Crotons.

[1] Coleman, L. C.—Diseases of the Areca Palm I. Myc. Series. Bull. II, Department of Agriculture, Mysore; also in Annales Mycologici. Bd. 8, 1910.

[2] Raedt van Oldenbarnevelt: De Koffiekultur op Java. 's Gravenhæ, 1898.

One of us (M. J. Narasimhan) has found a very considerable number of host plants in the Mysore malnad attacked by a Corticium which seems almost certainly to be C. koleroga. Certainty on this point could be attained only through the carrying out of cross-inoculation experiments. The following is the list of host plants found by him with the locality where the disease was found.—

Plant	Kanarese name	Locality
1. Jasminum sp. Scandent shrub.	.....	Koppa.
2. Randia dumetorum Lamk	Mangāre mara ...	Do
3. Tabernaemontana coronaria Br.	Nandibatlu ...	Agumbe and Talaguppa.
4. Gardenia gummifera Linn, f.	Bikke gida ...	Everywhere in the Malnad.
5. Wendlandia notoniana Wall.	...	Karur, Sagar.
6. Canthium parviflorum Roxb.	Kare gida ...	Koppa, Karur.
7. Pavetta sp. ...	.....	Guntenaik Estate, Sollebail.

In the case of Jasminum sp. this author was able to observe the disease actually spreading on to coffee leaves from leaves of the Jasminum which had twined itself about the coffee bush.

From the above observations it seems clear that the black rot fungus has a number of different host plants and this has to be taken into account in considering measures for controlling the disease.

We are now in a position to consider the course of the disease and the measures to be taken for combatting it. In typical black rot areas it begins to make its appearance toward the end of June, or about two or three weeks after the break of the south-west monsoon. Fresh infection starts, in the majority of cases at least, from the old leaves which had been attacked the previous year. Infection must be very easy where such old leaves remain attached to the coffee trees or lodged among the tangled branches of a tree which has not been pruned or handled. It seems doubtful whether the fungus can spread from leaves lying on the ground up the stems. As already stated, one of us (M. K. Venkata Rao) could find little

evidence of the fungus on the main branches or stems and could in no case trace it to the ground, so the chances of spread from the ground upward seem remote. However there are considerable chances of dead leaves being blown up from the ground and lodged on the lower branches of coffee trees and this in all probability forms an important source of early infection.

After the fungus has once become established on the fresh leaves further spread takes place both through the basidiospores formed and through the active growth of the fungus from leaf to leaf and twig to twig. The extent to which basidiospores are instrumental in spreading the disease has not been ascertained but undoubtedly they play an important role. As already explained they become detached very easily and are readily washed from infected leaves. A driving rain and high wind may therefore spread them to considerable distances. However the chief means of spread is undoubtedly through direct mycelial growth from leaf to leaf.

Towards the end of the season sclerotial masses are as already stated, formed on the mycelial web and these carry the fungus through the dry season till the following monsoon.

From the above it can be seen that the first step to be taken in reducing the attack of this fungus is to remove as far as possible, sources of infection. The fact that unpruned and neglected portions of estates are, according to our observations, likely to become infected earlier than those portions which have been properly attended to indicate the importance of removing dead leaves and twigs associated with them which may harbour the resting stage of the fungus. With regard to old diseased leaves on the ground it would probably be advisable to bury them by a light digging but actual experiments have not been carried out to prove this. The removal of other host plants growing in the neighborhood is also a matter of some importance.

Finally there is the question of spraying with a fungicide such as Bordeaux mixture to prevent the spread of the disease. Considerable work has been done by us as also by Frattini[1] on this question and the results obtained indicate that spraying will check the disease fairly

[1] Frattini—Summary of Experiments conducted by the Scientific Assistant o Mysore, 1917.

effectively. It is doubtful if spraying a whole estate is at all a practical proposition on account of labour difficulty. However, it seems to us that the spraying of patches, which from their position, are liable to severe attack and are thus likely to form the chief centres from which the disease will spread, can and should be done. The cost of spraying is not excessive. M. K. Venkata Rao found the cost to work out at between Rs. 18 and Rs. 19 per acre in experiments conducted by him. The cost will depend considerably on the nearness of water-supply. The water difficulty is probably the greatest one standing in the way of spraying at that time of the year. We would strongly advise trials of spraying on such patches accompanied of course by the careful pruning of trees and the burial through digging in of the old leaves. Whether spraying the mulch of leaves on the ground would be advisable seems doubtful. The fungus is confined to the lower surfaces of the leaves and it would be impossible to reach these surfaces except where the leaves lie upside down.

Conclusions.

1. Black rot or Koleroga of Coffee is caused by a fungus belonging to the order Basidiomycetes and known as Corticium koleroga (Cooke) Von Höhnel.

2. The fungus develops as a film or pellicle of mycelium on the twigs, the lower surfaces of the leaves and the berries. It produces the death of the leaves and berries it attacks.

3. The fungus apparently lives entirely superficially. It interferes with the respiratory activity by blocking the stomata and probably also attacks the tissue actively by the secretion of an enzyme or toxin.

4. The fungus develops during the south-west monsoon and is serious under conditions where the air remains saturated with moisture for long periods.

5. The fungus is carried over from one wet season to another by means of resting bodies. These are of the nature of sclerotia which are formed in the mycelial web on the attacked leaves and on attacked twigs and berries as well.

6. The fungus is spread during the monsoon by means of basidiospores which are formed, as far as has been observed, during a short period only; it is also spread

through the growth of the mycelium from infected on to uninfected portions.

7. The same or a very closely related fungus has been found upon no less than seven other species of plants which grow in the Mysore malnad. In the case of one of these, direct infection has been traced from the plant to a coffee tree.

8. Observations made indicate the advisability of removing all diseased twigs and leaves through pruning before the break of the monsoon so as to lessen initial infection. For the same reason the digging in of the mulch in badly diseased areas is also recommended.

9. To check the disease in areas where it is annually severe, trials of spraying with Bordeaux mixture are advised. This mixture should be prepared with an adhesive consisting of resin-soda or of calcium caseinate as tested and recommended by the Mysore Agricultural Department. Such spraying must be looked upon as a preventive rather than a curative treatment. It must be done before the break of the monsoon, that is, in late May or early June. This is one of the reasons why the addition of an adhesive is necessary. Another reason lies in the fact that the addition of an adhesive such as resin-soda or calcium caseinate, leads to a much more even distribution of the spray material. In other words it increases the wetting power of the spray. A later spraying in July or August after the disease has commenced would be difficult to carry out and would certainly not be nearly so effective. Fawcett's[1] observation that Bordeaux mixture does not kill the fungus seems to be a doubtful one and requires verification. In any case it does not affect the question of early spraying for it has been conclusively shown by the experiments conducted by Frattini and us that Bordeaux mixture does prevent the growth of the fungus on leaves not yet attacked.

The method of preparing Bordeaux mixture with these adhesives is appended.

1. Bordeaux mixture with resin-soda adhesive.

   (*a*) 5 lbs. of copper sulphate dissolved in 12 gallons of water.

   (*b*) 5 lbs. of lime slaked in 12 gallons of water.

[1] Fawcett—Bulletin of the Porto Rico Agricultural Experiment Station No. 17, 1915.

(*c*) 2 lbs. of resin and ½ to 1 lb. of soda heated in one gallon of water till quite clear (about an hour).

Pour (*b*) into (*a*) accompanied by constant stirring and then add (*c*) to make up the complete mixture.

2. Bordeaux mixture with calcium caseinate adhesive.

I. (*a*) 5 lbs. of copper sulphate dissolved in 12 gallons of water.

(*b*) 5 lbs. of lime slaked in 12 gallons of water. Pour (*b*) into (*a*)

II. (*c*) ½ lb. of casein soaked in ½ gallon of water.

(*d*) ½ lb. of lime slaked in ½ gallon of water.

Pour (*d*) into (*c*) and stir well till the casein dissolves and a syrupy mixture is obtained. This will take about 10 minutes.

Add II to I, stirring the solution all the time.

WD 1915—GPB—2,000—25-5-23

FIG. 1

Coffee leaves attacked by C. koleroga. The second from the left has become detached and is suspended by a mycelial strand. Another mycelial strand which has become displaced is shown running from the twig to the surface of the third from the left (A).

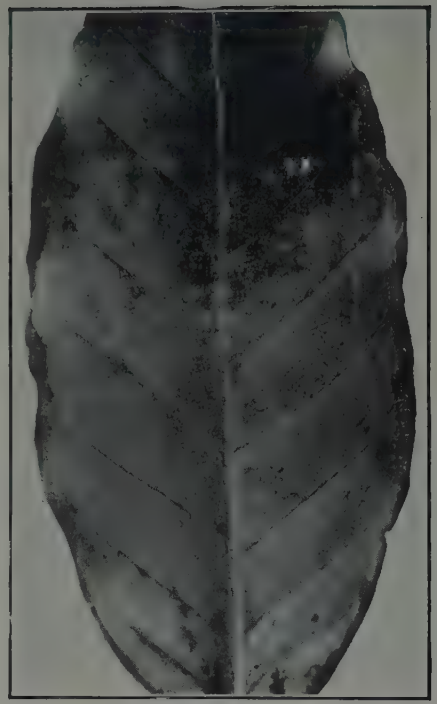

FIG. 2

Under surface of coffee leaf showing the dense web or skin formed by the fungus. The fungus has not yet extended to the apex of the leaf.

PLATE I.

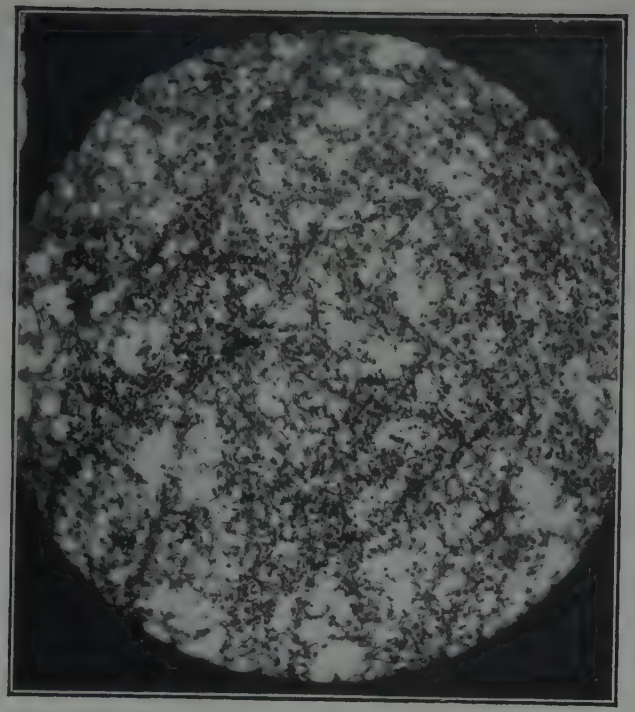

FIG. 1

Microphotograph of mycelial web showing development of basidia. The primary mycelial strands of parallel hyphæ, with the younger branches therefrom are readily to be made out.

FIG. 2

Small part of preparation shown in figure 1 photographed under a higher power to show basidia, sterigmata and basidiospores (A). Basidia with the sterigmata in the course of formation are to be seen at (B). One of the primary mycelial strands (C) is shown plainly in this figure.

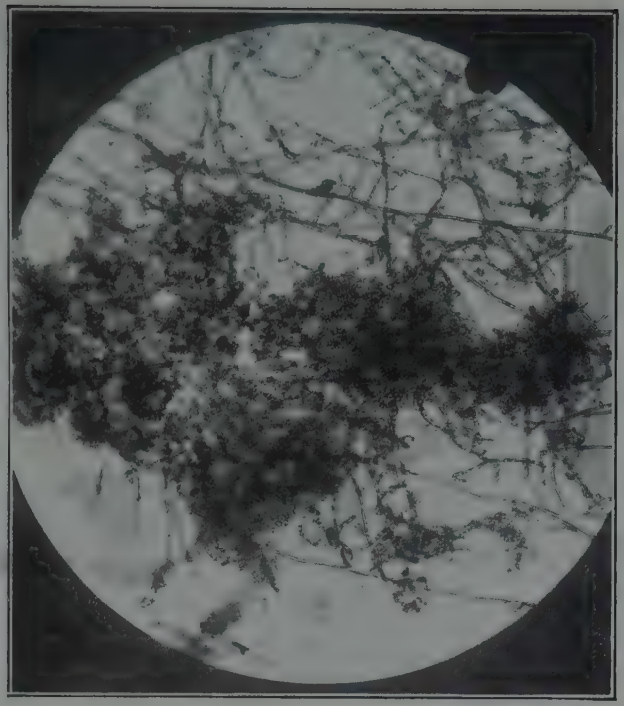

FIG. 1

Microphotograph of old mycelial web from under surface of leaf showing sclerotial structures.

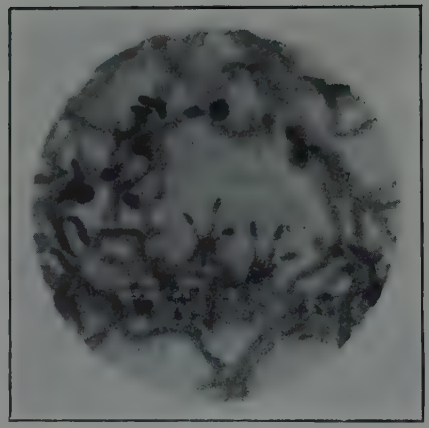

FIG. 2

Small part of preparation shown in Pl. II, Fig 2 magnified to show basidia and the basidiospores laterally attached to the tapering sterigmata. Some of the detached basidiospores are to be seen clearly.

PLATE III.

FIG. 1

Pure culture of C. koleroga on Oat agar.

FIG. 2

Pure culture of C. koleroga on sterilised potato cylinder. The formation of the typical strand is shown clearly in the lower part of the figure.

PLATE IV.